MiniBooNE: Current Status.

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INFO05, Santa Fe.

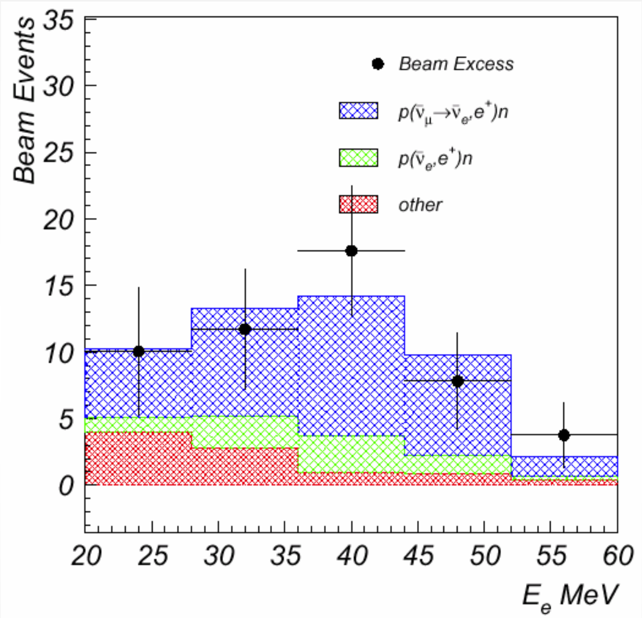
July 11, 2005

Talk Outline

- Motivation for MiniBooNE.
- The MiniBooNE experiment:
  - Description.
  - Data.
- Conclude.

LSND and KARMEN

searching for $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$

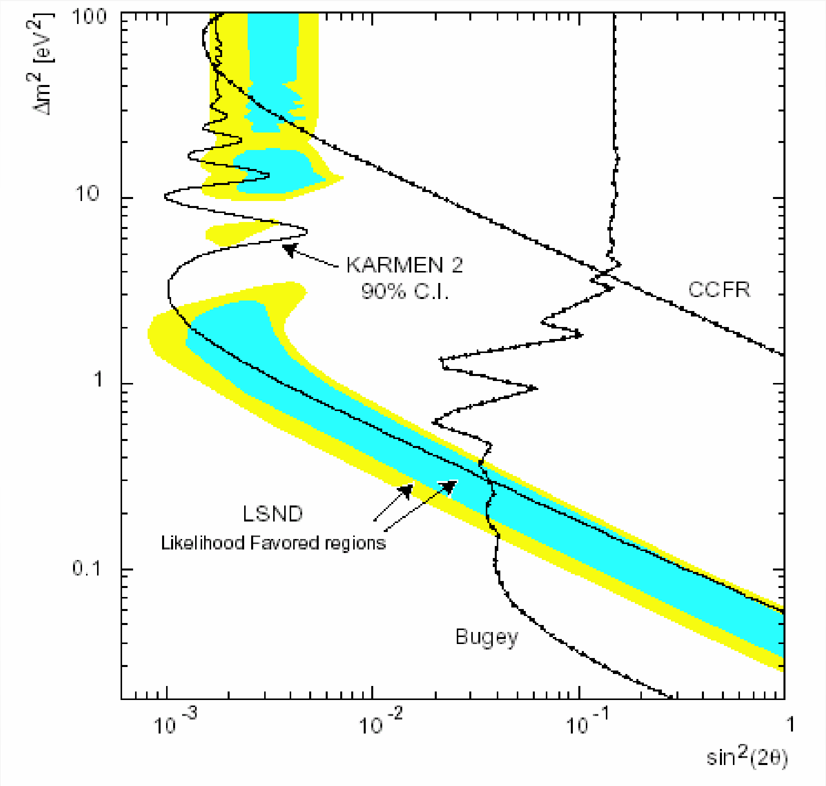


Signal above background:

87.9±22.4±6.0 events

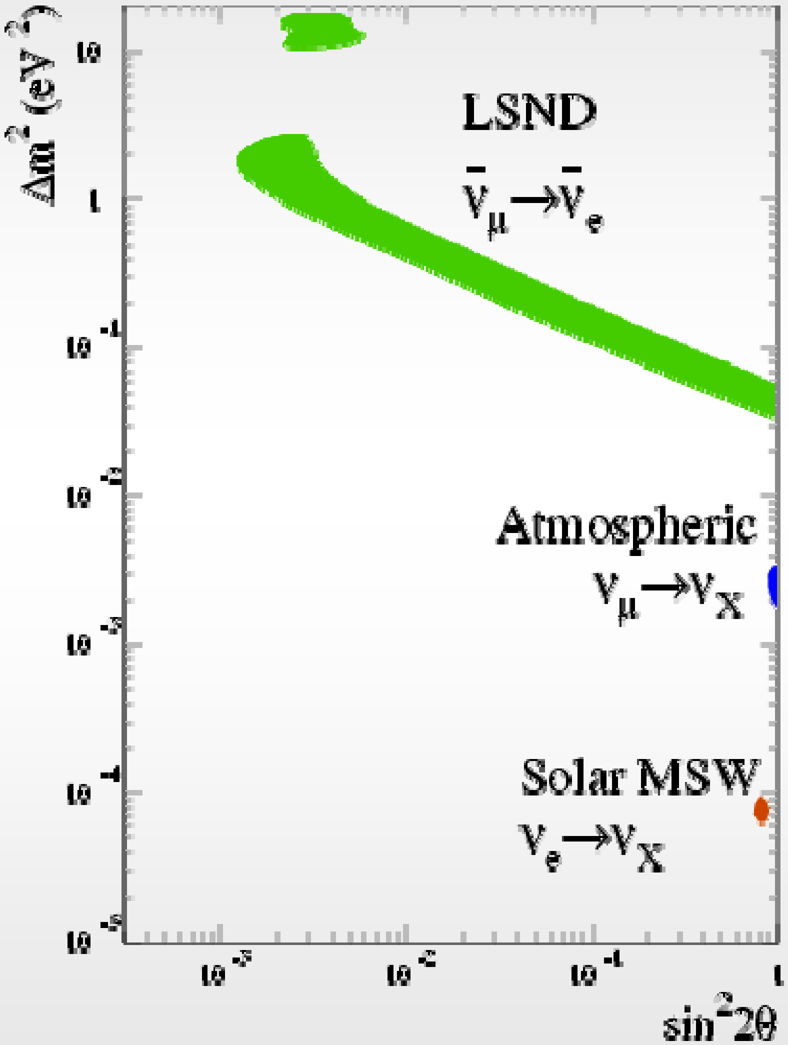
Oscillation probability:

(0.264±0.067±0.045)%



KARMEN 2 partially excludes LSND region.

Why MiniBooNE?



- Results from the LSND experiment and solar and atmospheric neutrino experiments can be explained by neutrino oscillations with distinct values of Δm^2.
- The Standard Model, with only 3 neutrino flavors, cannot accommodate all the Δm^2 values.
- Either one or more of the results is not due to oscillations, or there is physics beyond the Standard Model.

The BooNE Collaboration

- 13 universities and 2 national laboratories

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Enter MiniBooNE

The Booster Neutrino Experiment

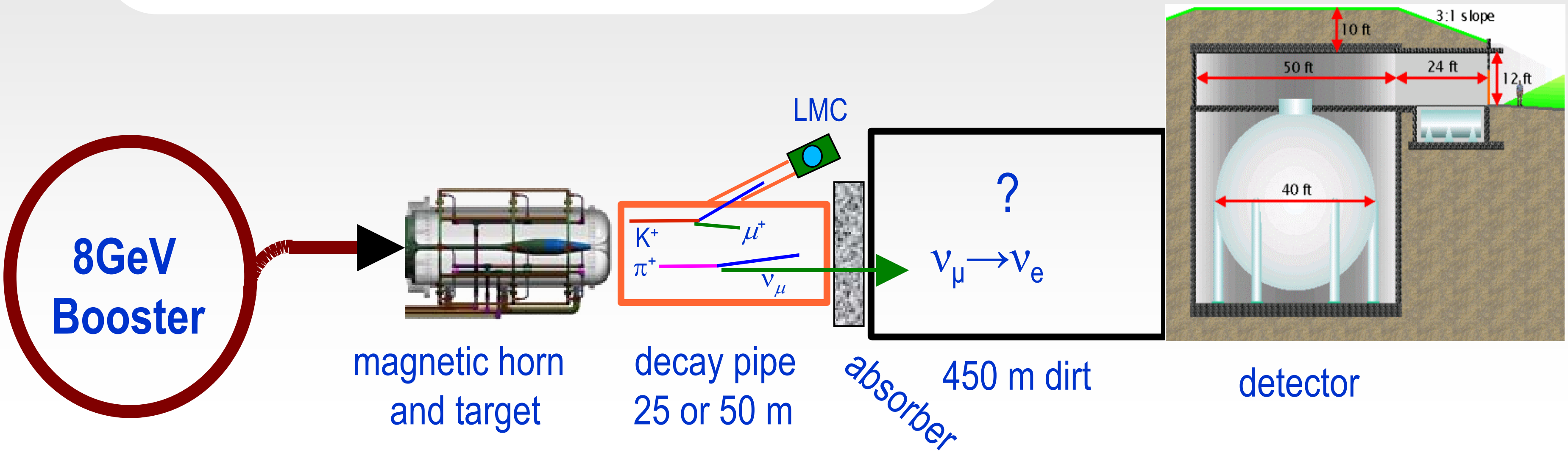
Proposed summer 1997.

The goal: to confirm, or exclude, the LSND result and extend the explored oscillation parameter space.

•Different systematics: beam energy $\times$10 LSND, event signatures and backgrounds different.

•Anticipated >4σ significance over entire LSND region.

MiniBooNE Overview



The FNAL Booster delivers 8 GeV protons to the MiniBooNE beamline.

The protons hit a beryllium target producing pions and kaons.

The magnetic horn focuses the secondary particles towards the detector.

The mesons decay, and the neutrinos fly to the detector.

- Signal from $\pi^+\to\mu^+\,\nu_\mu$ …then… $\nu_\mu\to\nu_e$ …which produces… e^- in the detector.

The FNAL Booster

– an accelerator in its 30s!

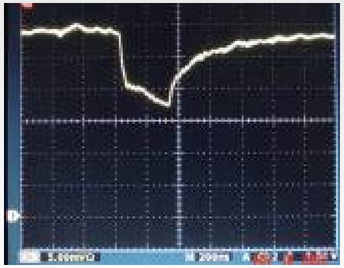
Built to deliver 8 GeV protons to the Main Ring. It now supplies the Main Injector, and the MiniBooNE and NUMI beamlines.

This far exceeds the initial design, and continues to prove challenging.

The Booster has never worked so hard!

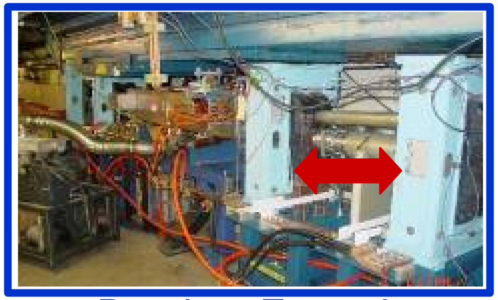
Linac & Booster Improvements


New Lambertson


Notching in Linac


Collimator System


4 Large Aperture Magnets in MI8 line

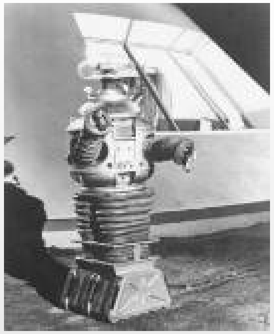

Dog-Leg Extension


MP01 Supply


New Damper

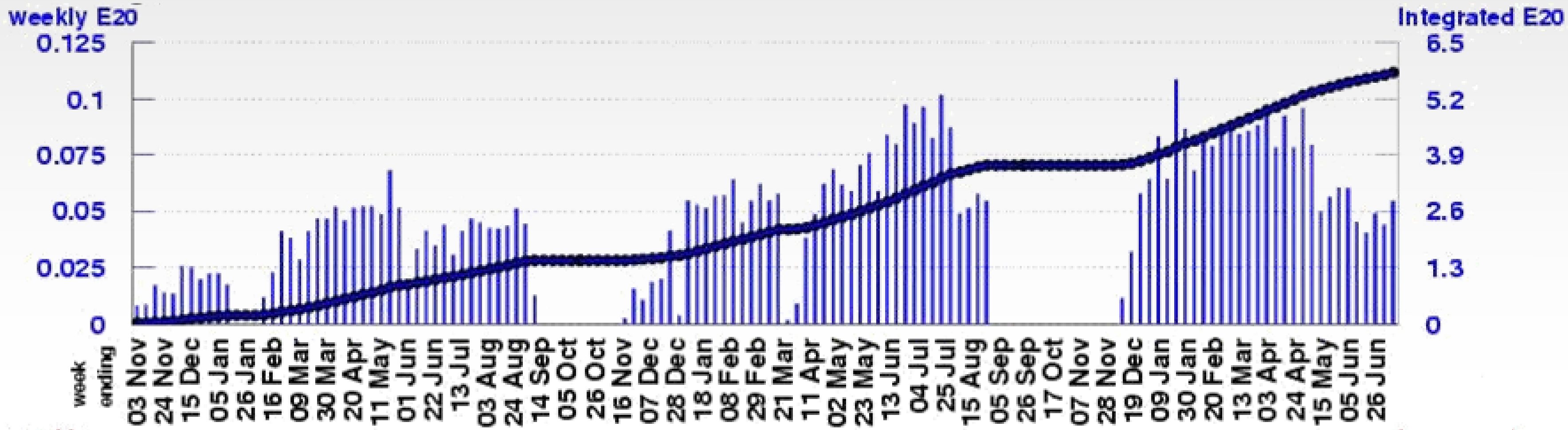

Larger RF Cavities


Booster Monitoring


Radworker Robot

and…
LCW upgrade,
vacuum upgrade,
profile monitor,
beam whacker,
hose replacement,
better survey…

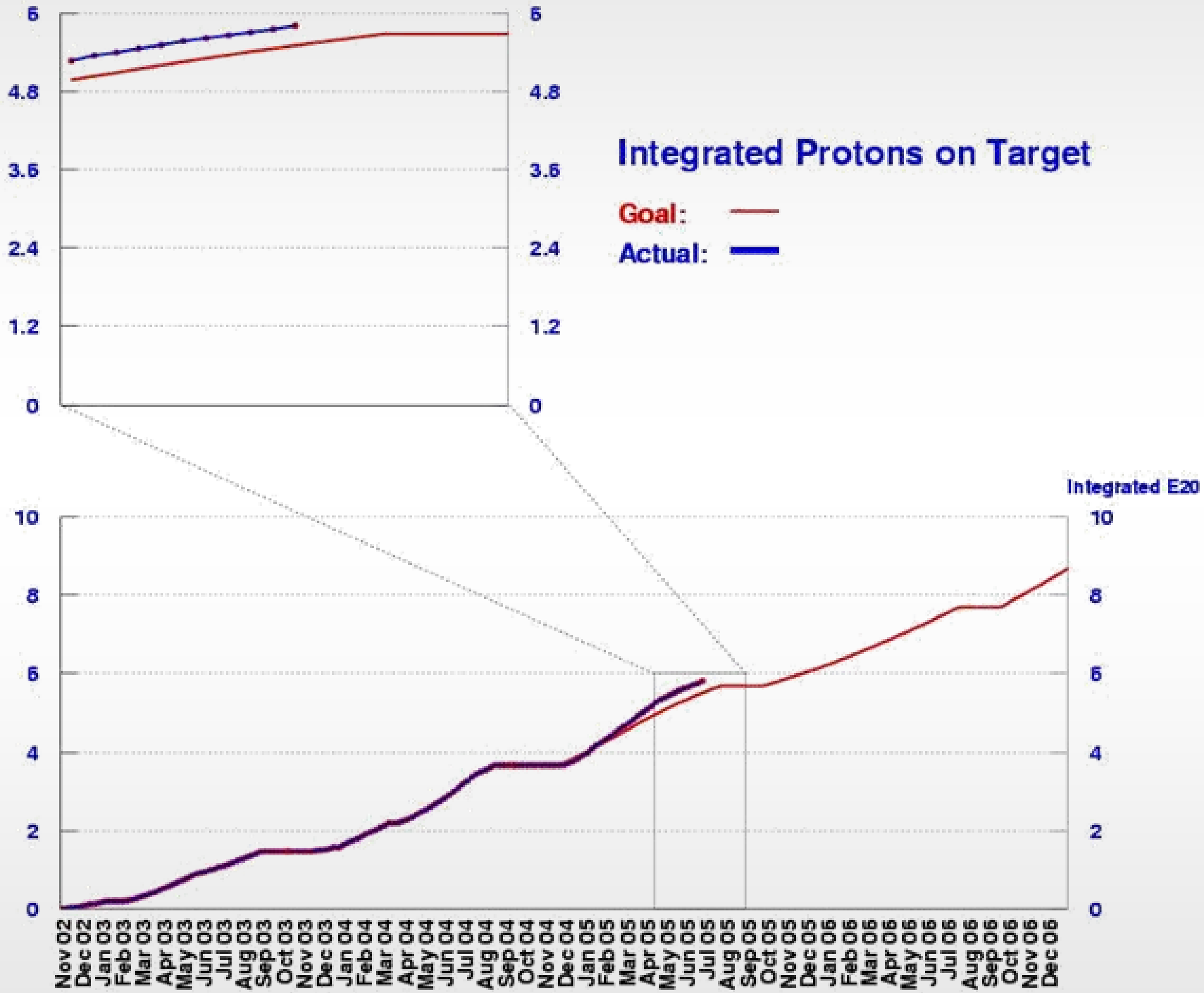
Booster Performance



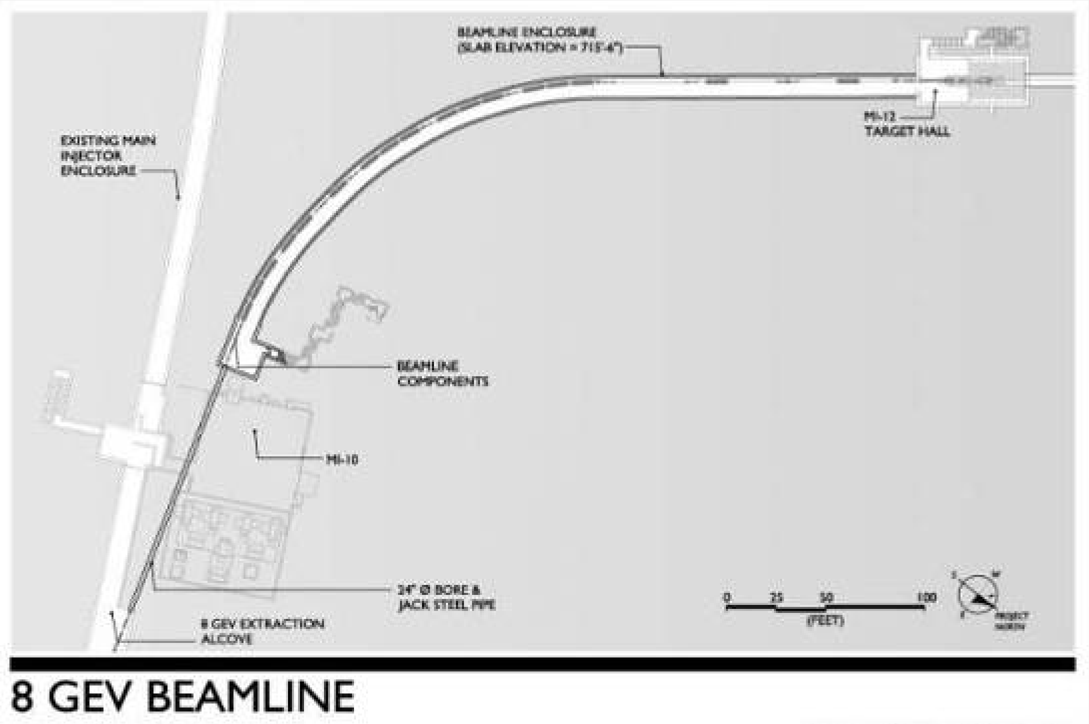
Booster performance has steadily improved over the run.

Thanks to the FNAL Accelerator Division for doing a great job!

Booster Performance



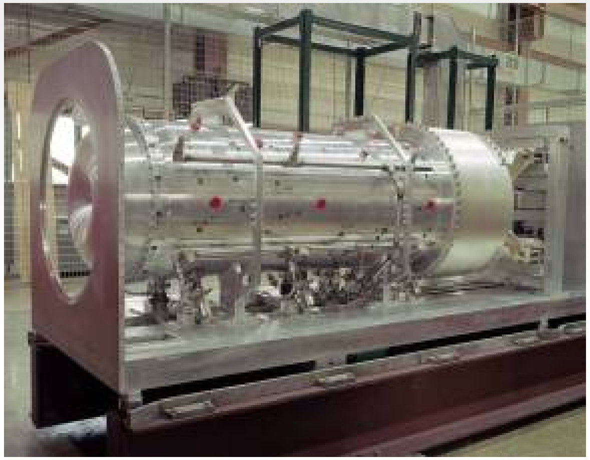
The MiniBooNE Beamline

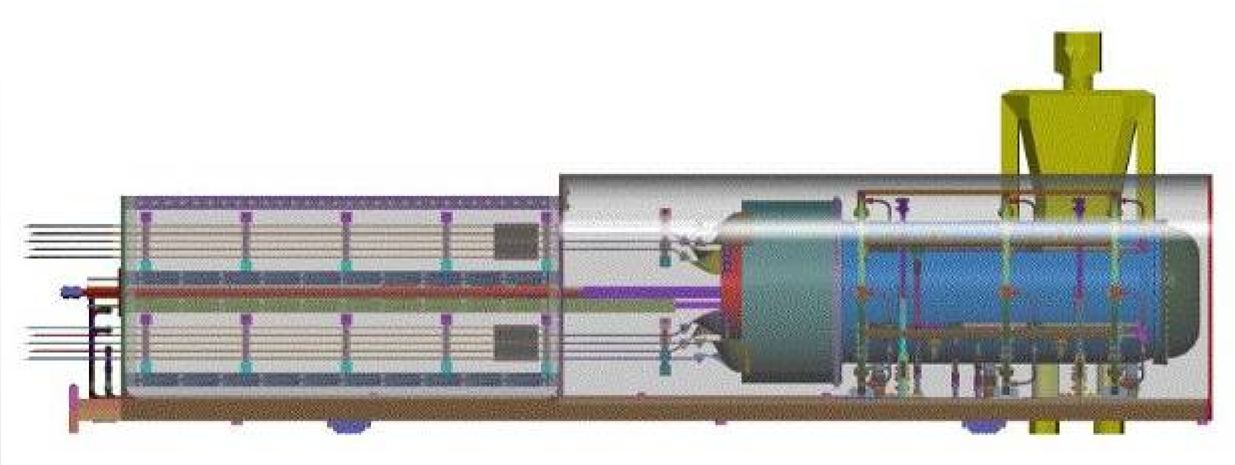


The Target and Horn

The horn focuses secondary particles produced in the Be target using a torroidal magnetic field.

170kA for 140μsec @ 5Hz.





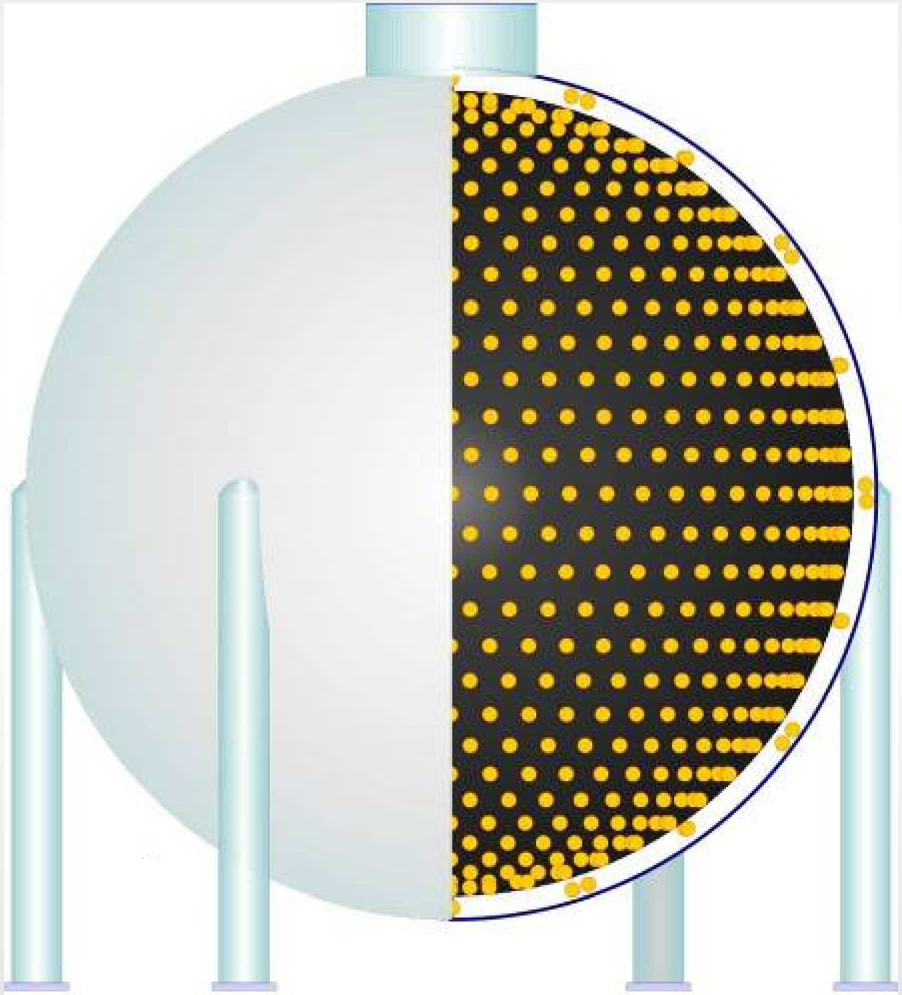
The First Horn – RIP

- We built the world's longest lived horn – it survived 96 million pulses at the fastest pulse rate ever (5 Hz average, 15 Hz instantaneous).
- The first horn lasted over two years (April 28, 2002 to July 28, 2004).
- There was no sign of fatigue failure anywhere.
- Corrosion, causing a ground fault, was the ultimate killer.
- Improvements to the spare horns should allow them to live even longer than the first.

The Funeral Procession

The MiniBooNE Detector

- •12 m diameter detector.
- •250,000 gallons of mineral oil.
- •Optically isolated inner region with 1280 8" PMTs, giving 10% coverage.
- •Outer veto region of 240 8" PMTs.

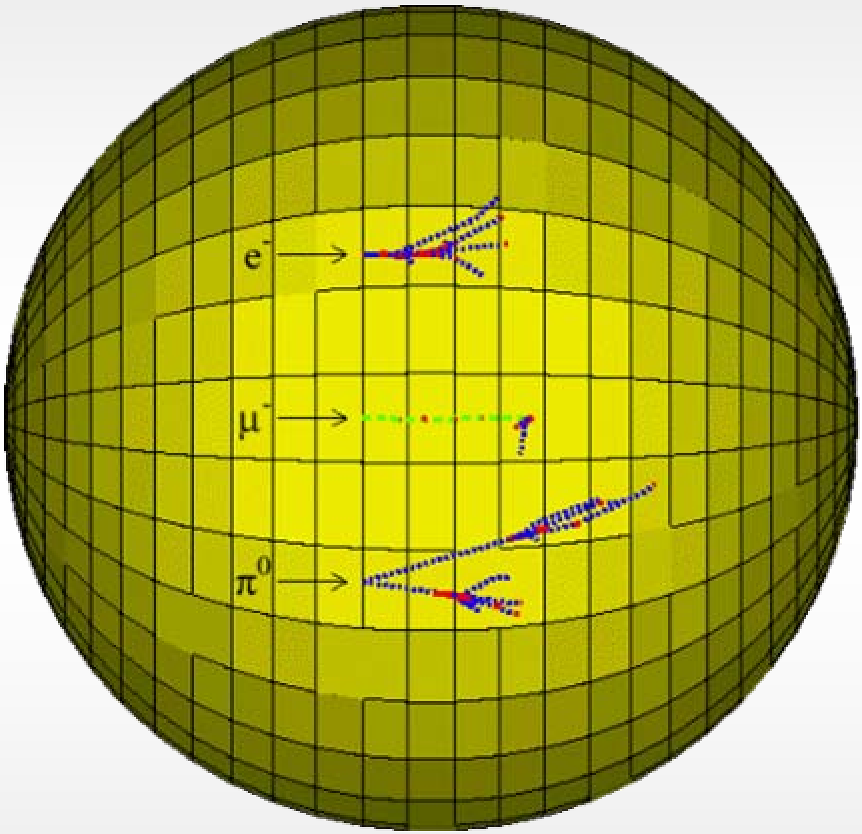


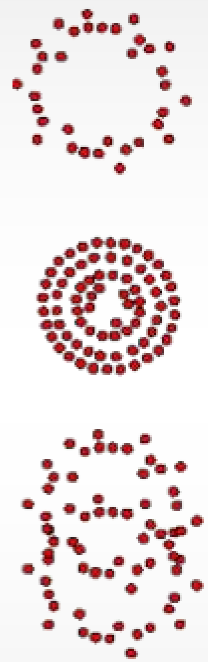
Detector Electronics

- Electronics are from LSND.
- Charge and time information is digitised every 100 ns, and transferred to a circular buffer with 2048 registers.
- In this way, the state of the detector for the most recent 204.8 μs is always known.
- The “protons on target” beam trigger arrives early, allowing calibration triggers to be vetoed, and the potential neutrino events to be placed within a 20 μs trigger, regardless of the detector’s internal trigger state.

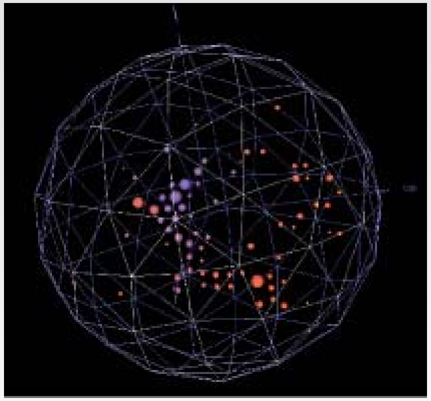
➢Electronics and PMTs proving to be very reliable.

Detector Response

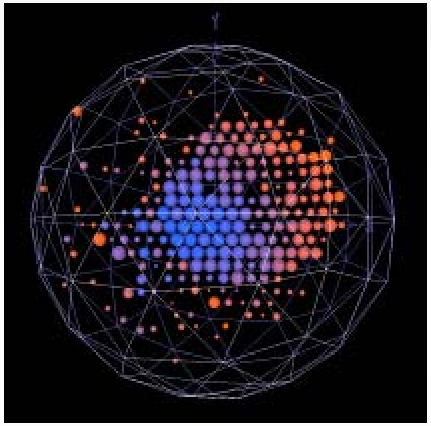




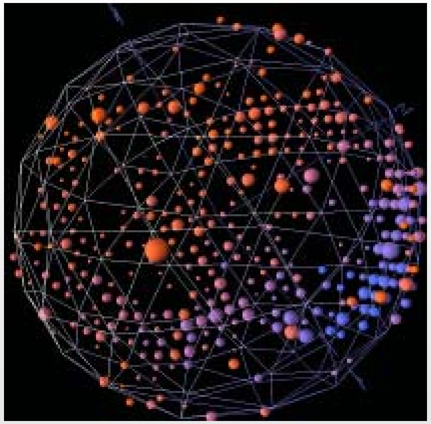
Michel e candidate



Beam μ candidate

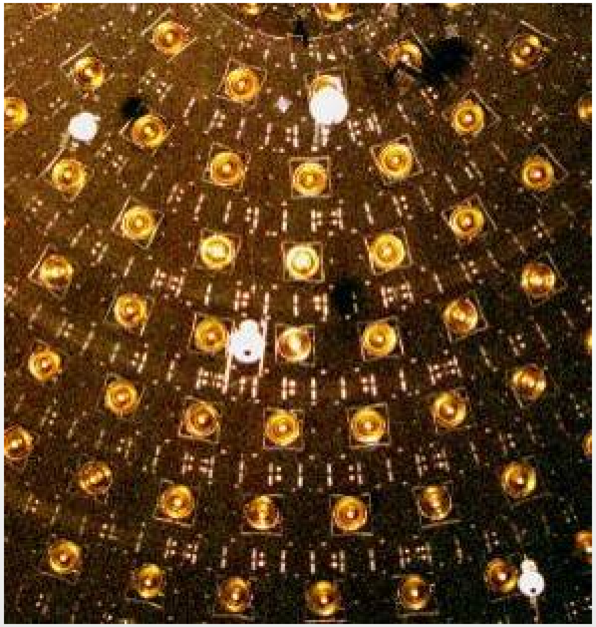


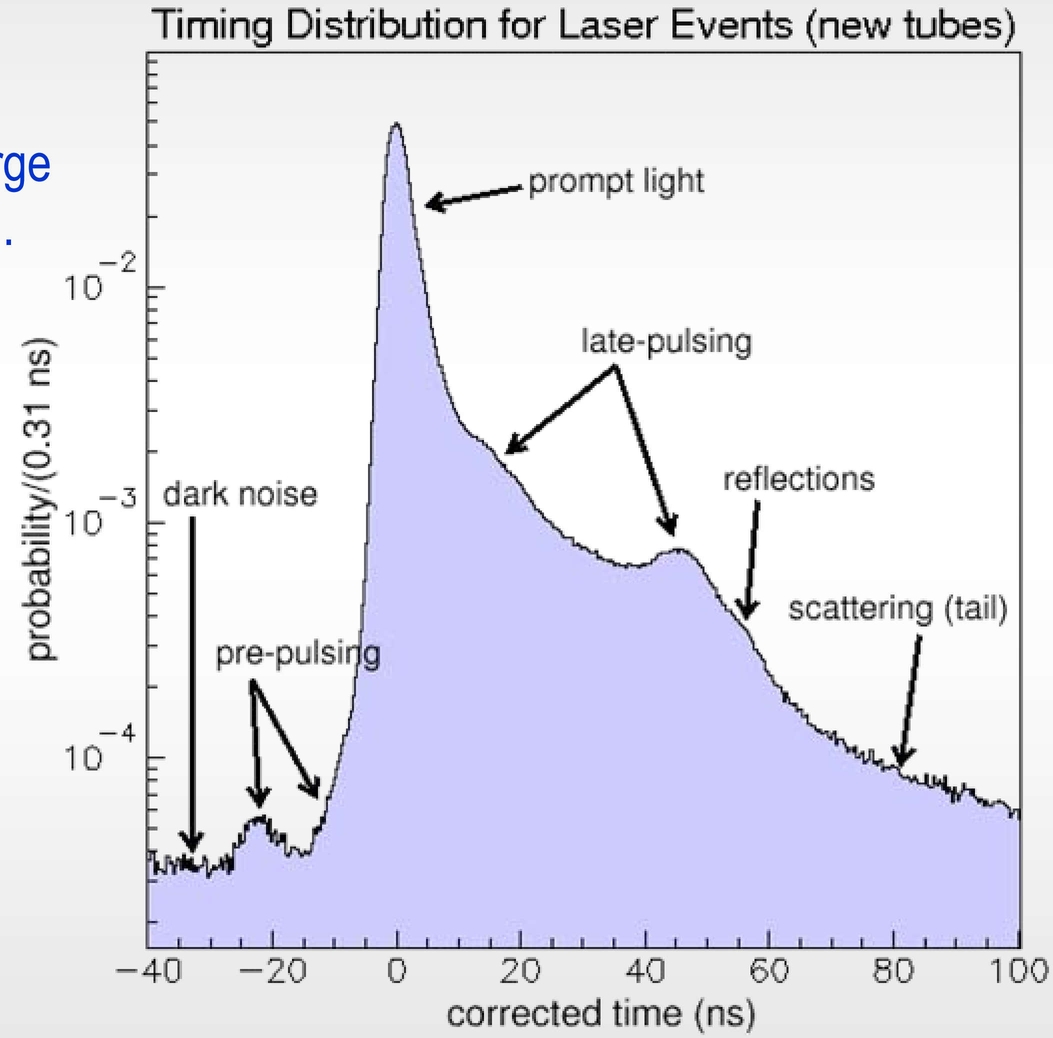
Beam π^0 candidate



Laser Calibration System

Laser flasks provide continuous PMT charge and timing calibration.





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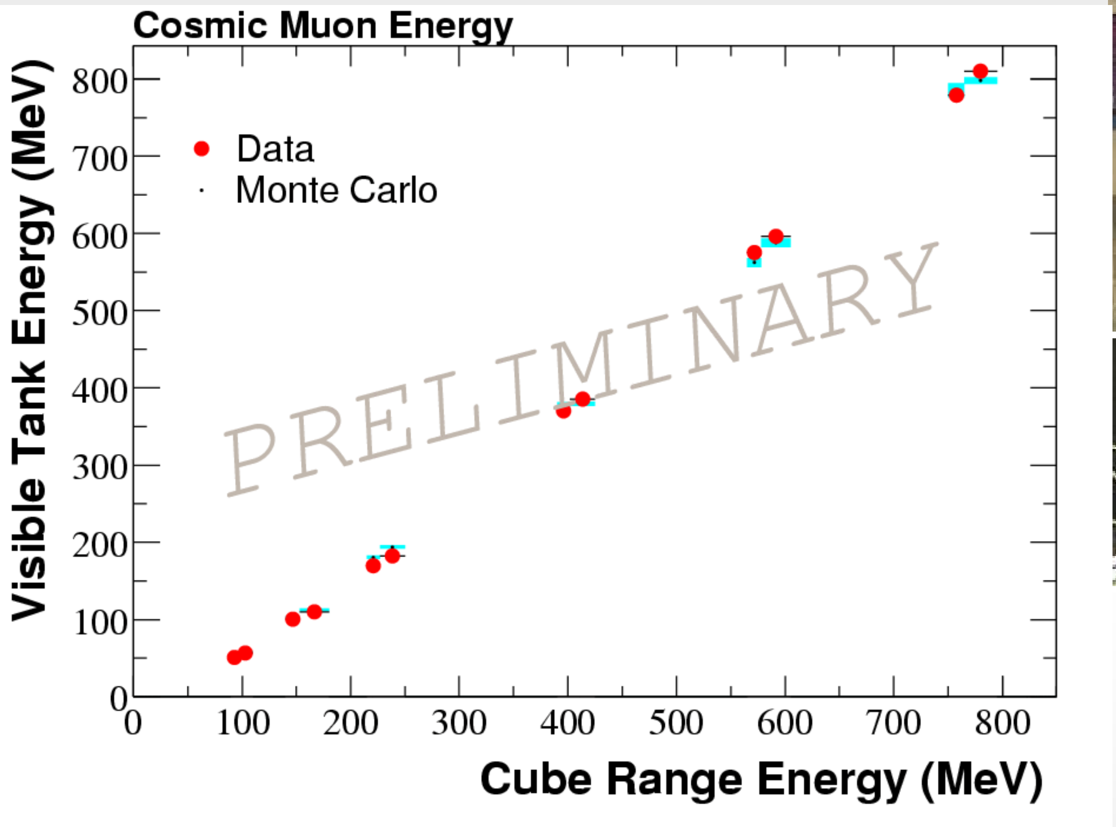
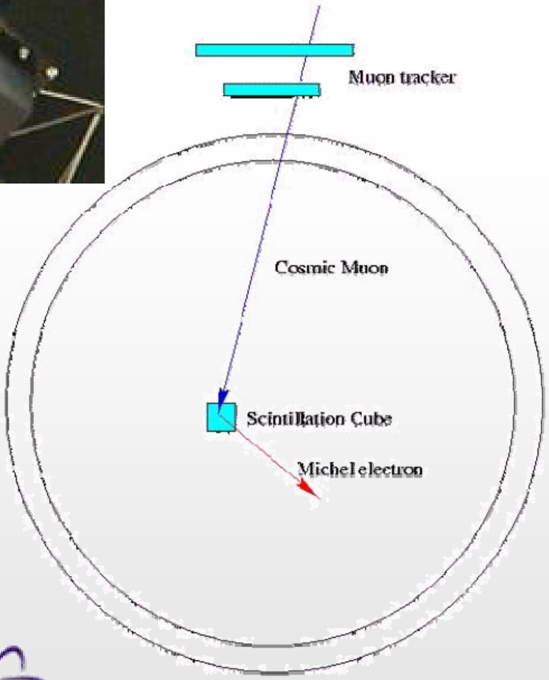
Muon Tracker





Muon tracker above detector and 7 optically isolated scintillator cubes in the detector provide cross checks for energy estimation and reconstruction algorithms.

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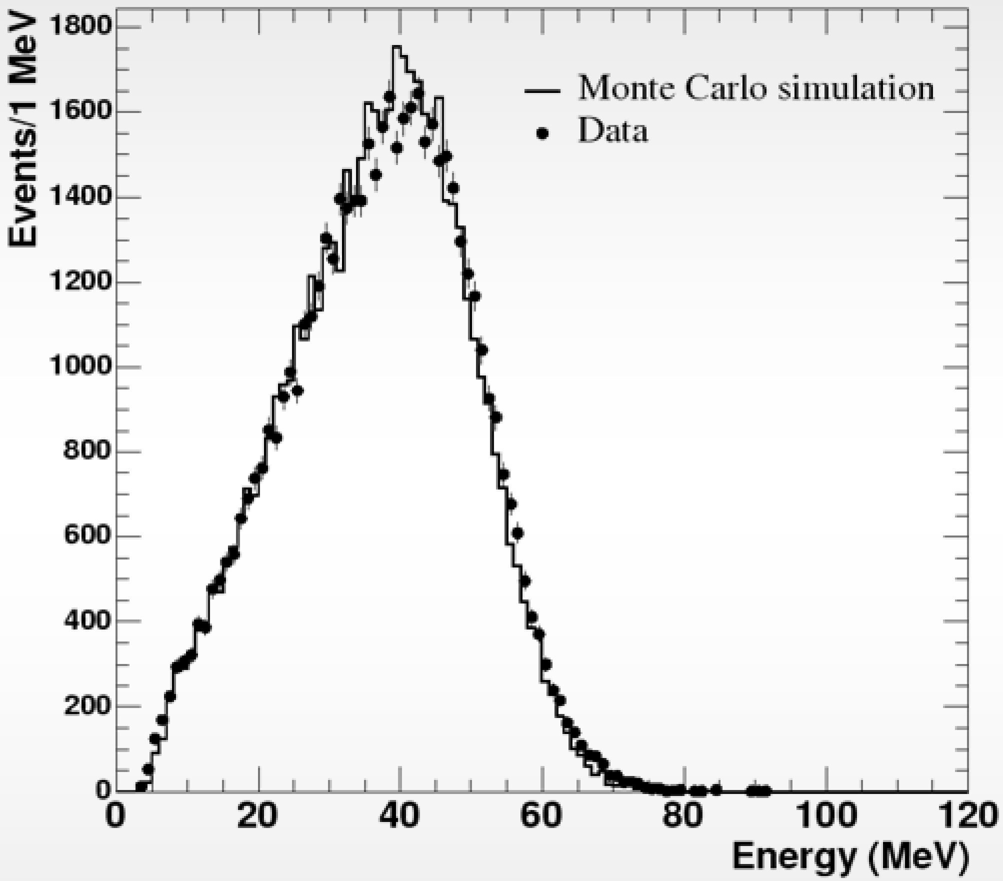
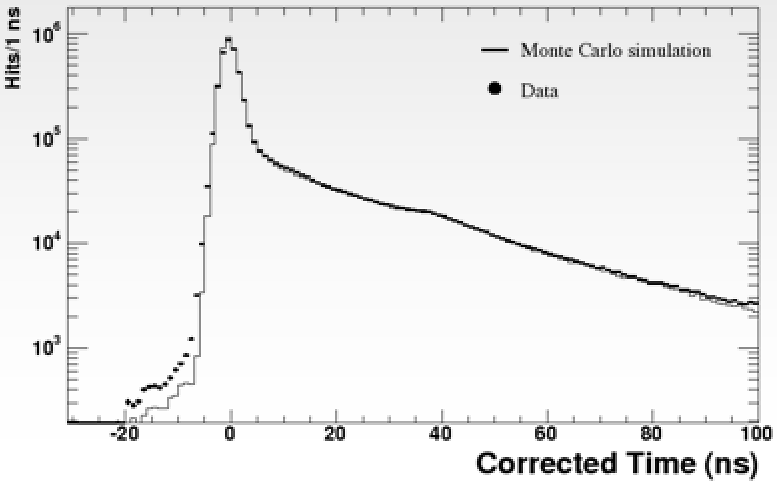
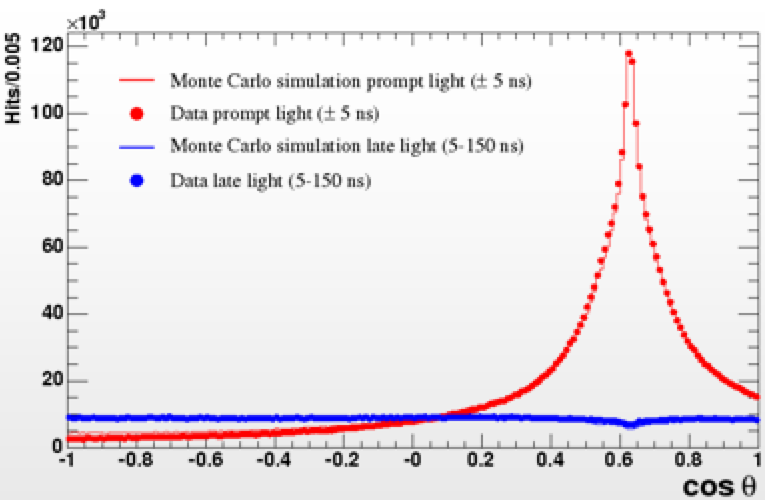
Michel Electrons







15% energy resolution at endpoint.

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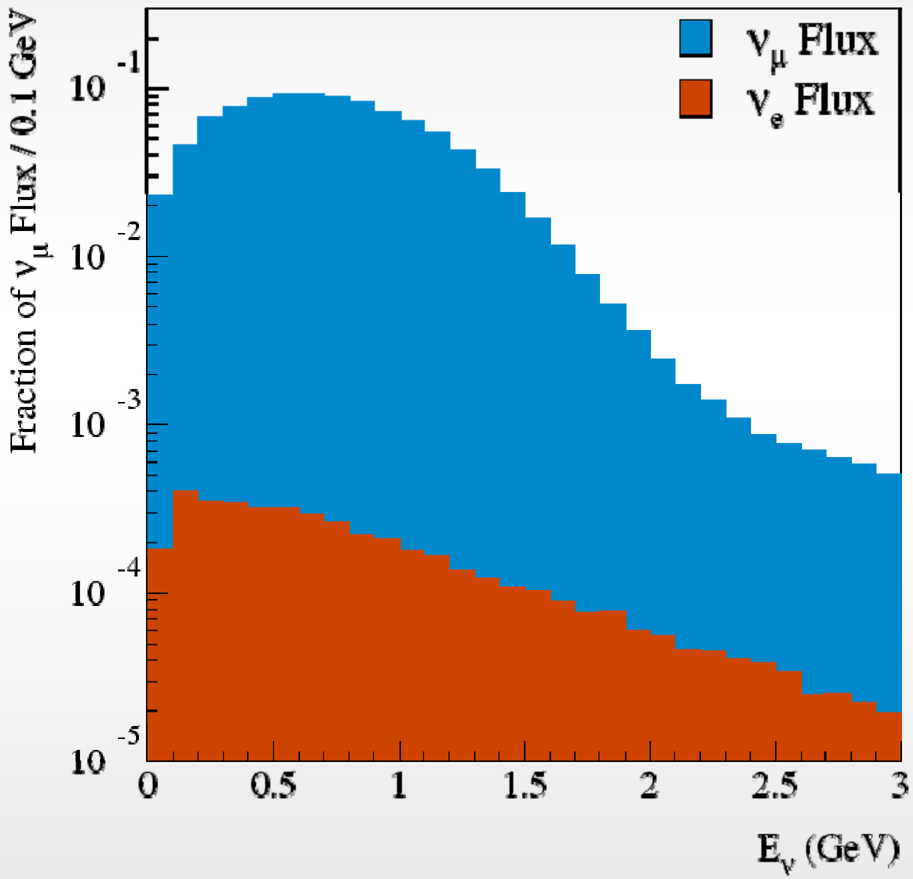
ν Flux at the Detector



8 GeV protons on Be target gives:

$p + Be \rightarrow \pi^+ , K^+ , K^0_L$

ν_μ from:

$\pi^+ \rightarrow \mu^+ \nu_\mu$

$K^+ \rightarrow \mu^+ \nu_\mu \qquad K^0_L \rightarrow \pi^- \mu^+ \nu_\mu$

ν_e from:

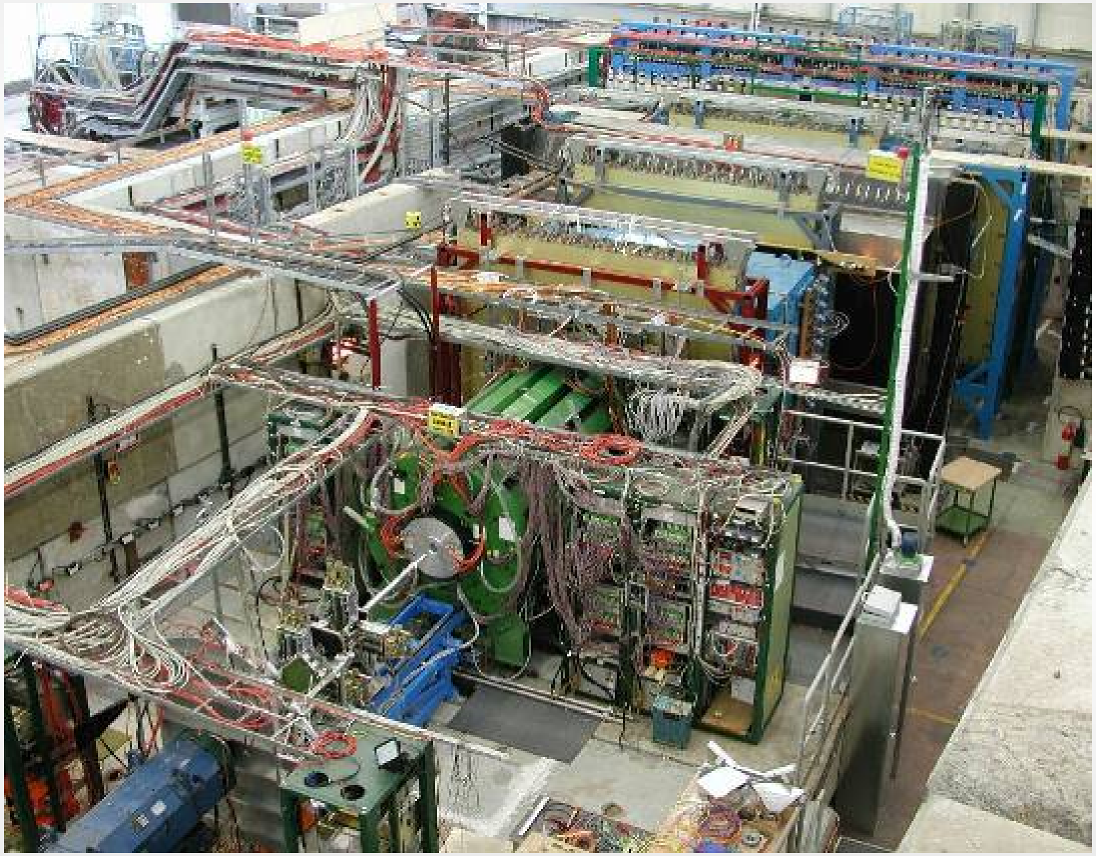
$\mu^+ \rightarrow e^+ \nu_e \bar{\nu}_\mu$

$K^+ \rightarrow \pi^0 e^+ \nu_e \qquad K^0_L \rightarrow \pi^- e^+ \nu_e$

Pion contribution from JAM S-W parameterization.
MARS/GFLUKA for kaon contribution.

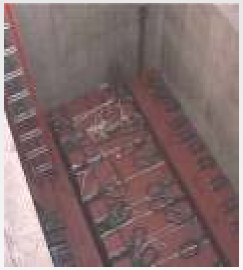
Beam Backgrounds

Secondary particle production from 8 GeV protons on an actual MiniBooNE target has been measured at HARP.



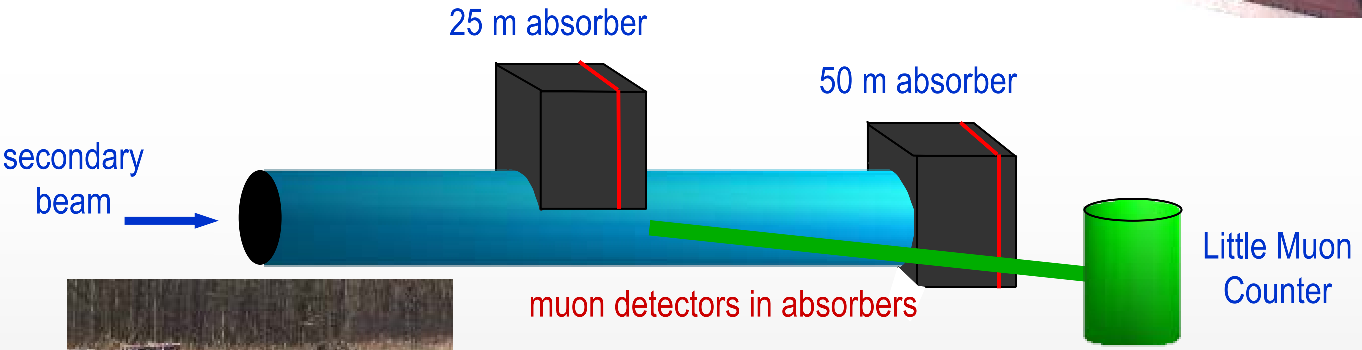
➢HARP results coming soon!

Beam Backgrounds



Varying the position of absorber checks the μ background.
Changing from 50 m to 25 m will:

- Decrease a genuine signal by a factor of 2.
- Decrease a signal from μ decay by a factor of 4.
- Have no effect on a signal from short lived sources.



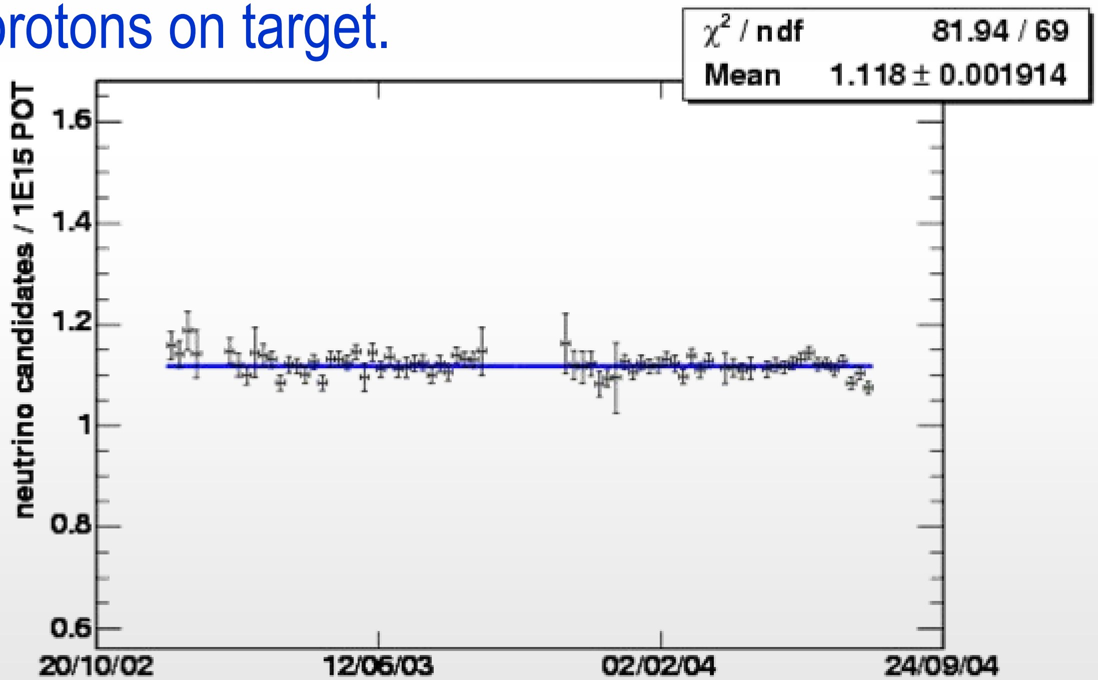
The Little Muon Counter (LMC) exploits wide angled kaon decays to measure the kaon production rate.

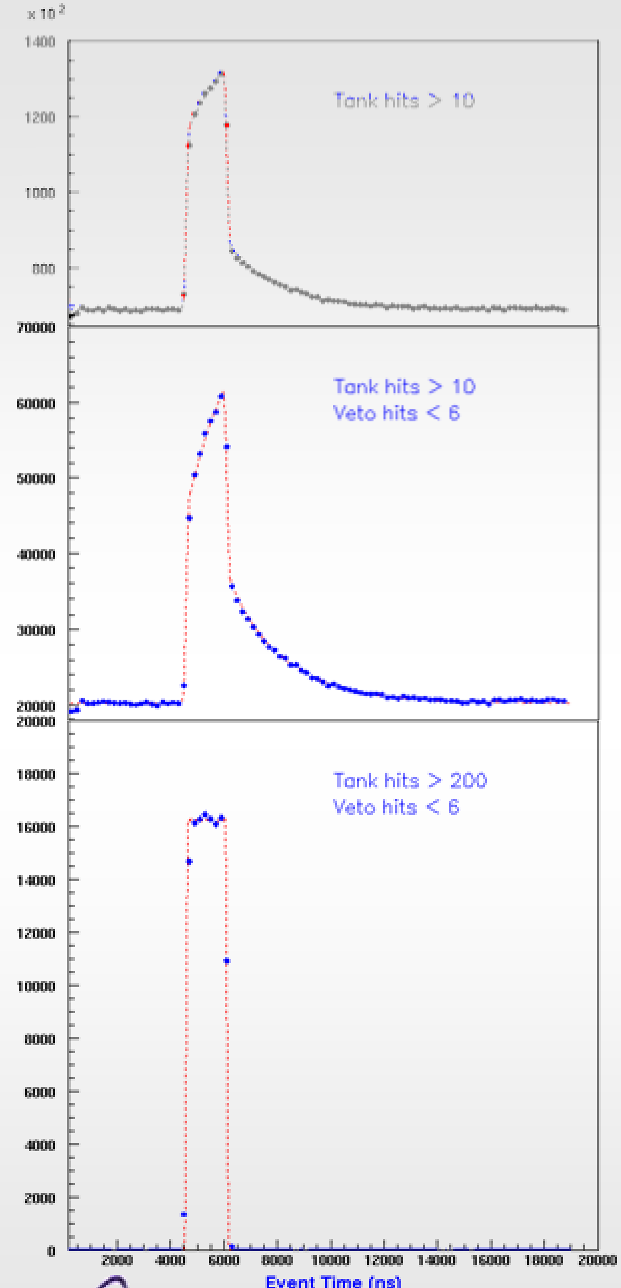
Neutrino Events

- the world's best short baseline ν beam

No high level analysis needed to see neutrino events.

➢611k neutrino candidates in 5.8×10^{20} protons on target.





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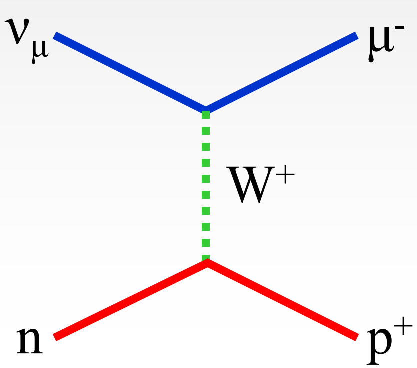
The Data

CC Quasi-elastic



- Simple topology.
- Kinematics give E_ν and Q^2 from E_μ and Θ_μ.
- **ν_μ disappearance analysis.**

NC π^0 Production

resonant:

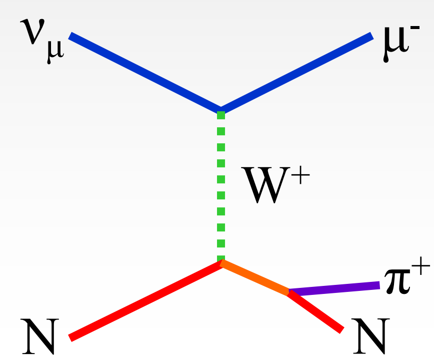
$$\nu + (p/n) \rightarrow \nu + \Delta$$
$$\Delta \rightarrow (p/n) + \pi$$

coherent:

$$\nu + \mathrm{C} \rightarrow \nu + \mathrm{C} + \pi^0$$

- $\pi^0 \longrightarrow \gamma\gamma$.
- Reconstruct invariant mass of the two photons.
- **Background to the ν_e appearance analysis.**

CC Resonant π^+



- Fledgling analysis.
- Should help disentangle nuclear interaction model.
- CCPiP oscillation search?

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CC ν_μ Quasi-elastic

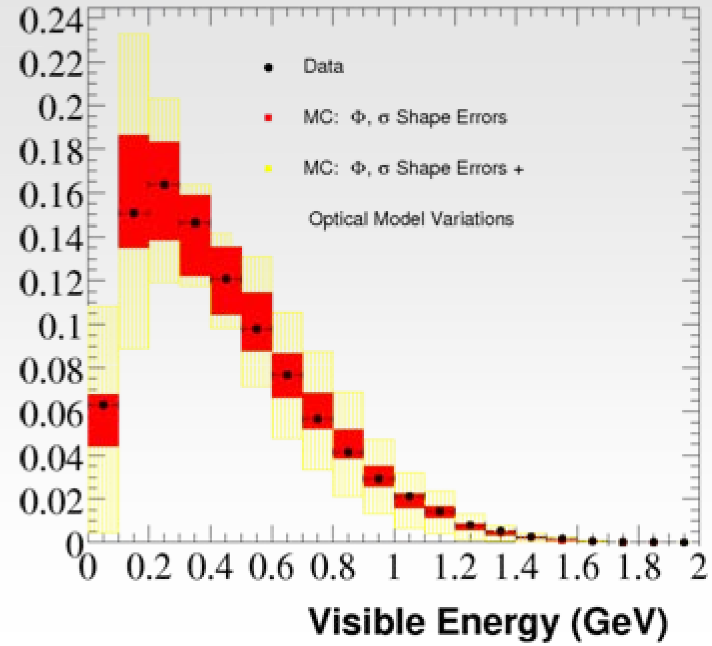
Selection based on PMT hit topology and timing. ~80% purity in remaining dataset.

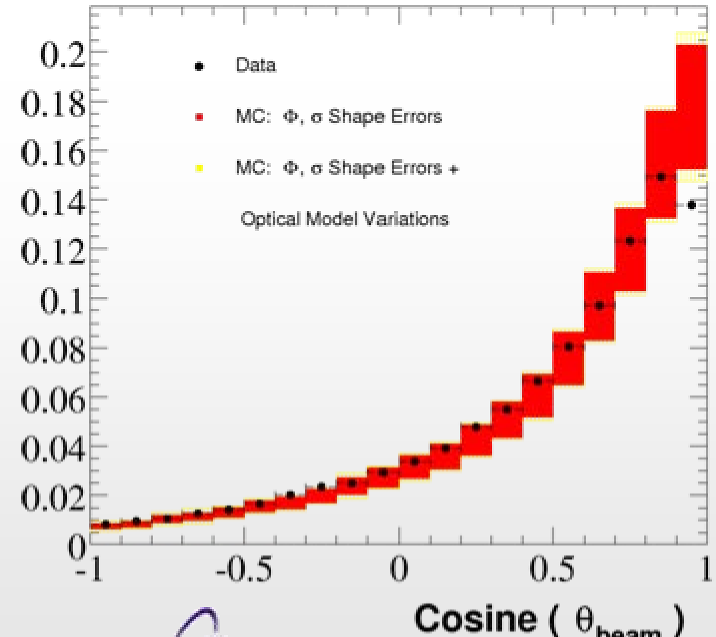
Data and MC relatively normalized.

Red band: Monte Carlo with current uncertainties from

- flux prediction.
- σ_{CCQE}

Yellow band adds optical model variations.





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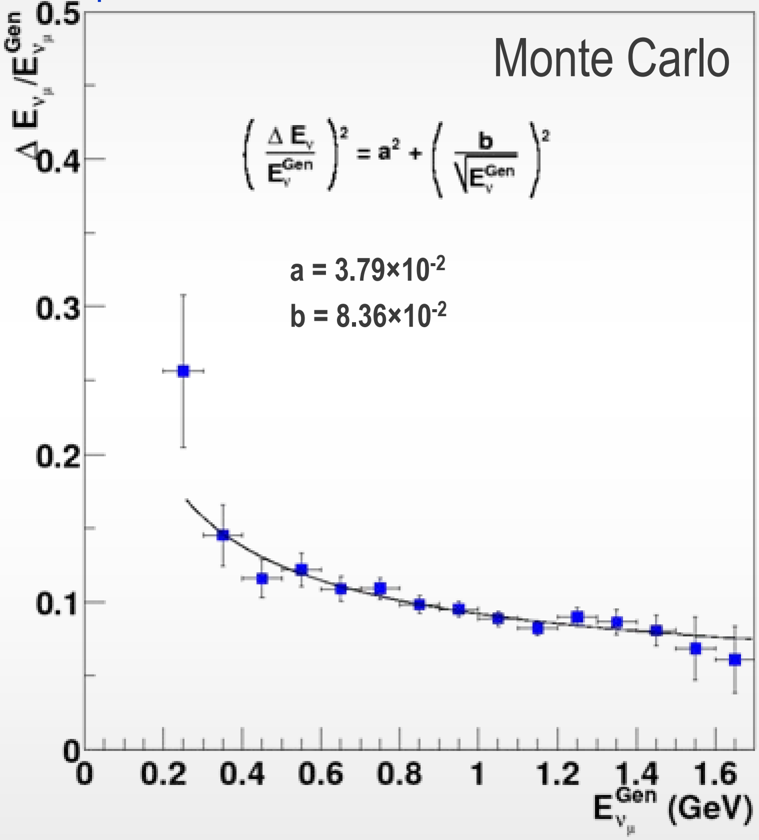
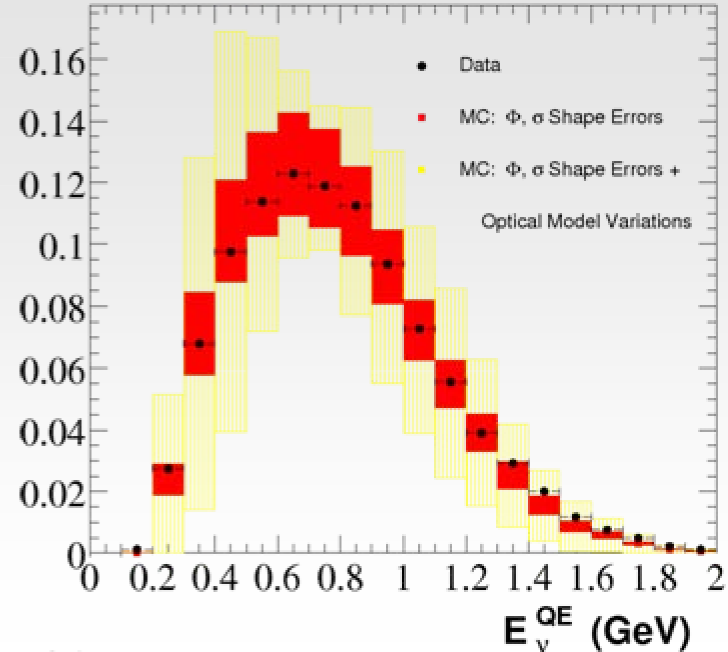
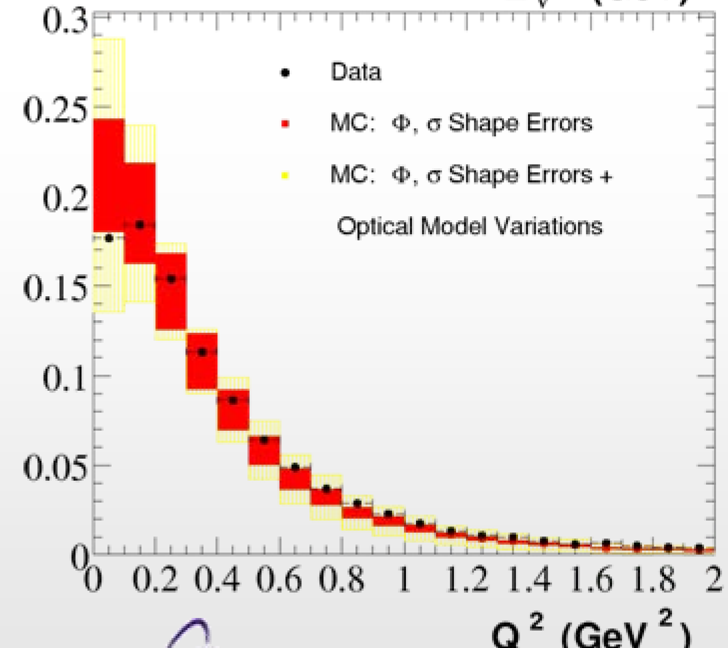
CC ν_μ Quasi-elastic

CC ν_μ energy resolution.



<10% for E_ν>800 MeV





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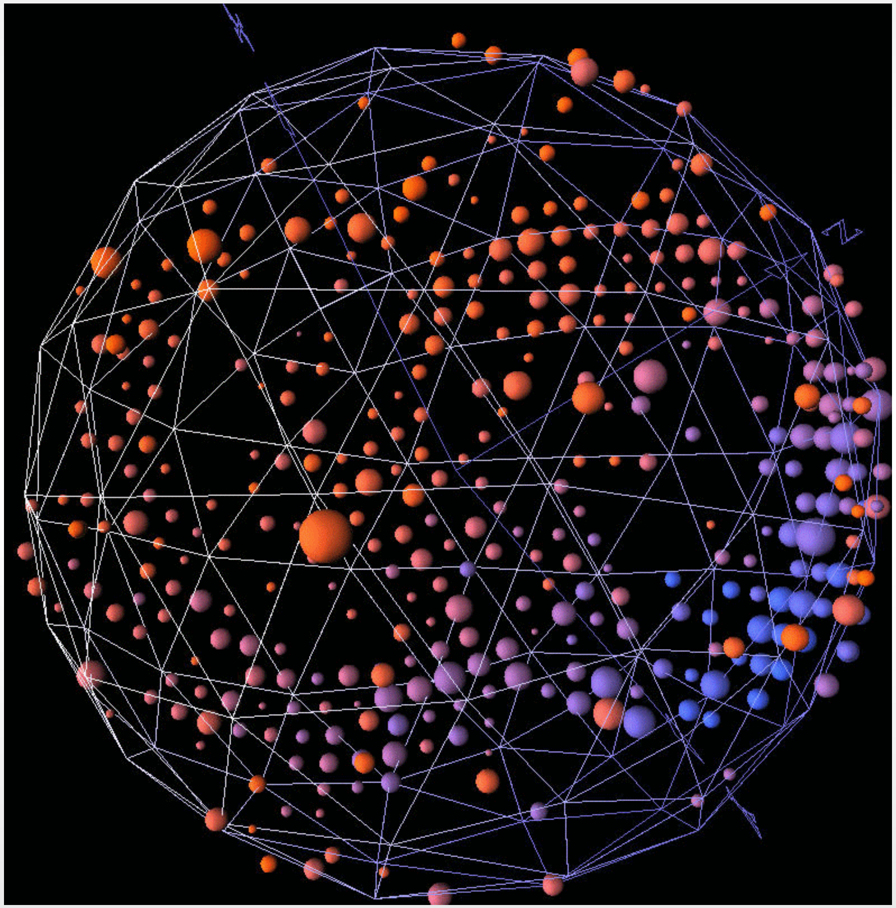
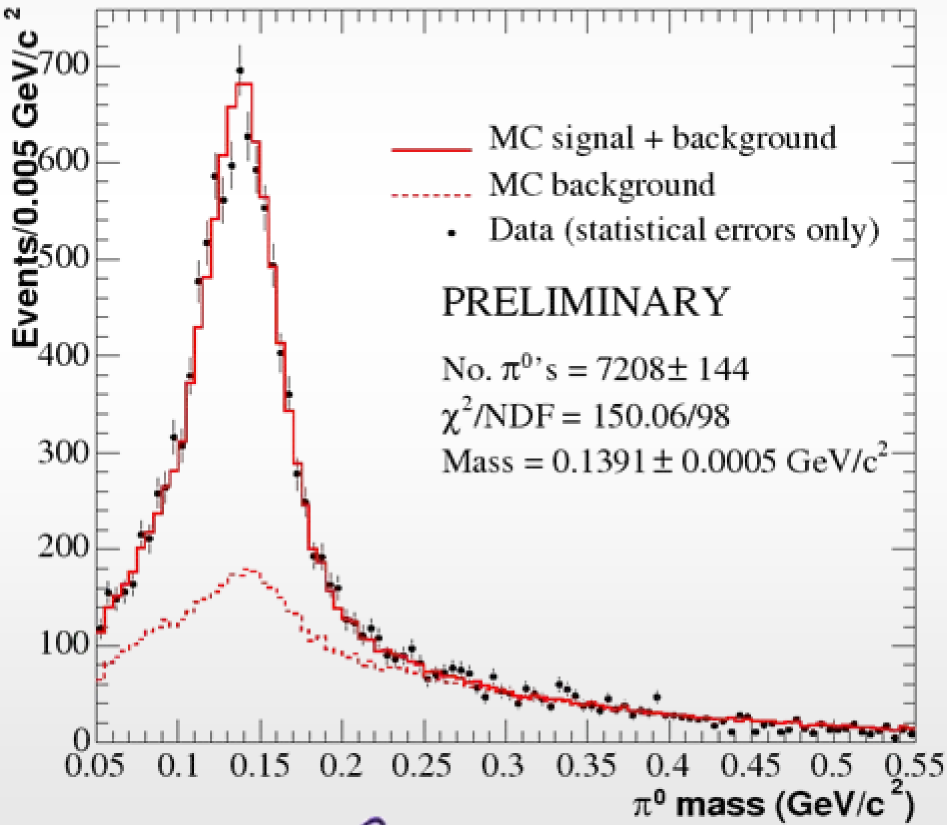
NC π^0 Production

- N_{TANK}>200, N_{VETO}<6, no decay electron.
- Perform two ring fit on all events.
- Require ring energies E_1, E_2 > 40 MeV.
- Fit mass peak to extract signal yield and background (shape from Monte Carlo).





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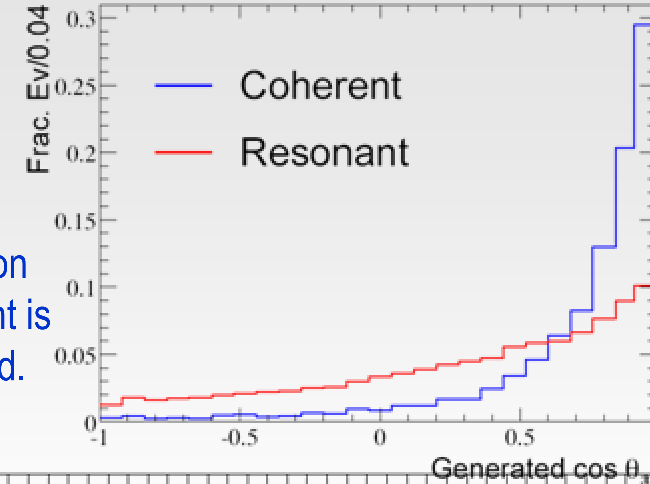
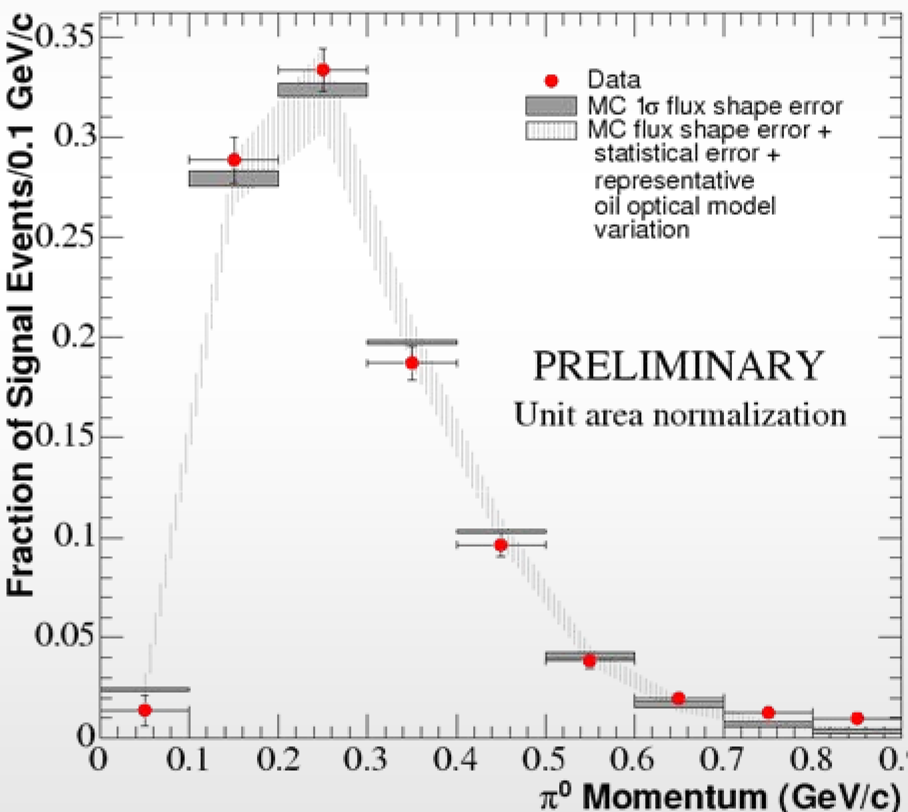
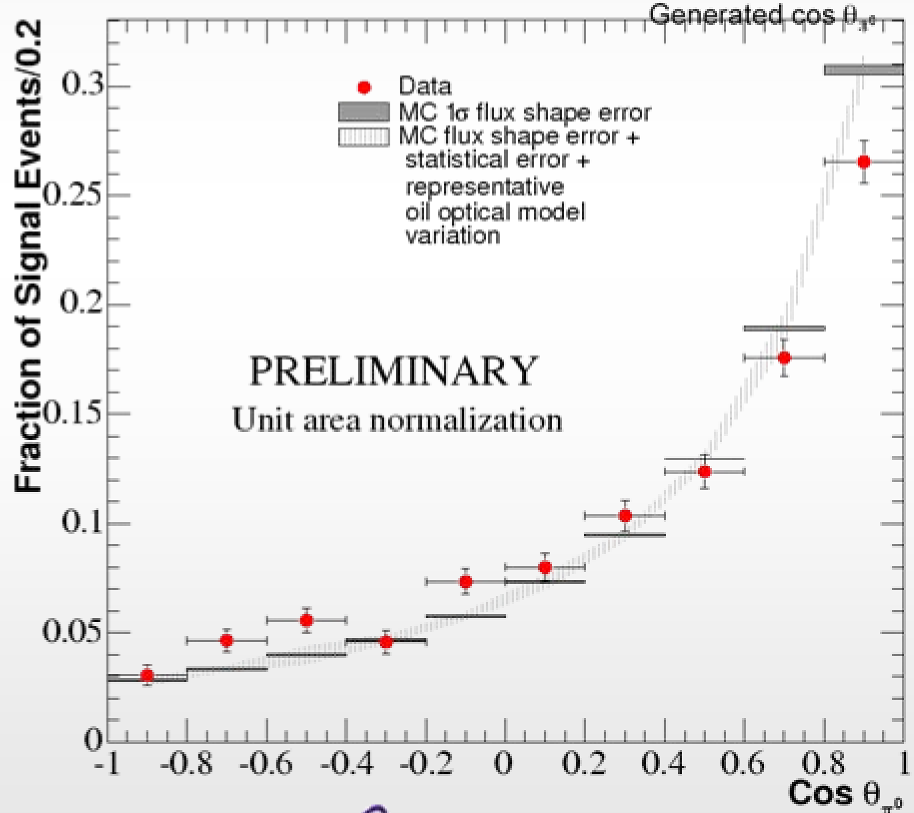
NC π^0 Production

Errors are shape errors
Dark grey : flux errors
Light grey : optical model

Sensitive to production mechanism. Coherent is highly forward peaked.







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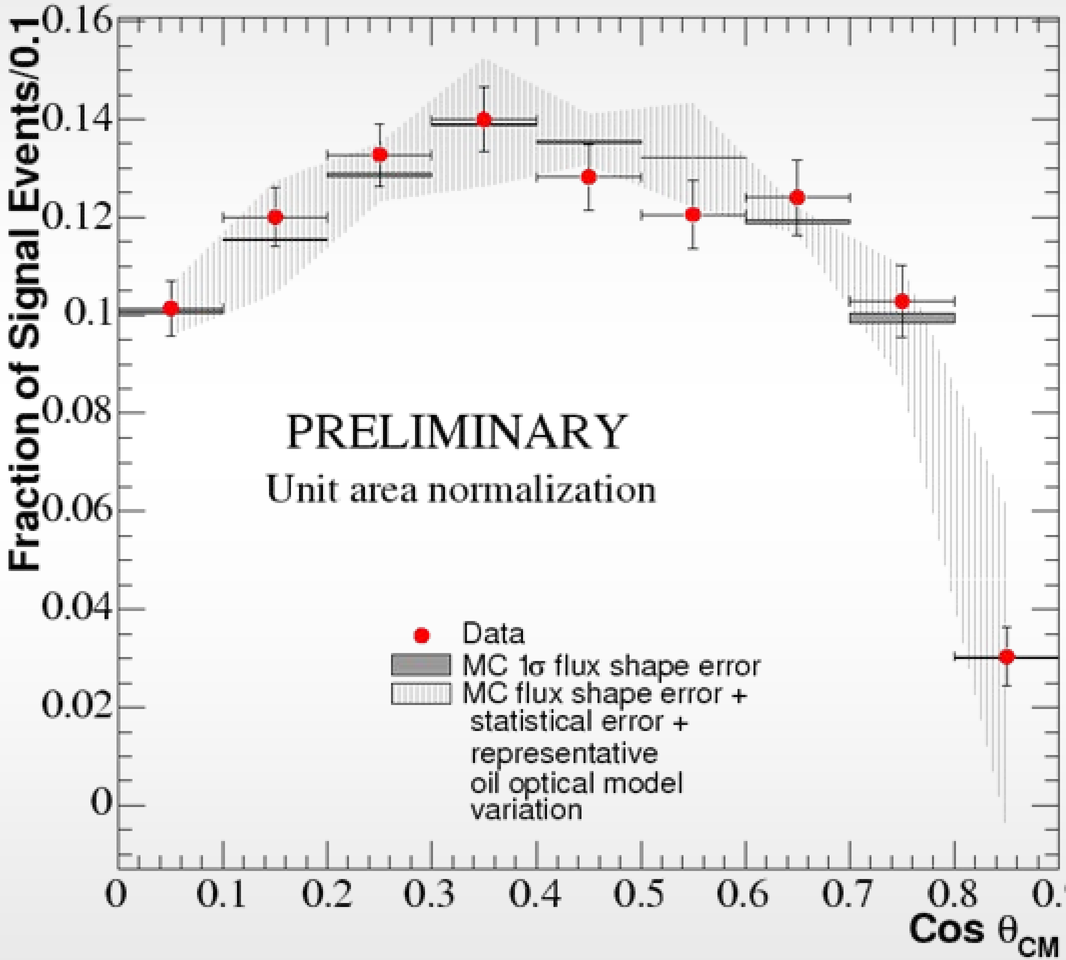
NC π^0 Production

CM frame		lab frame
$\Theta_{CM} = \pi/2$ $\cos\Theta_{CM} = 0$	⇨	small γ γ opening angle
$\Theta_{CM} = 0$ $\cos\Theta_{CM} = 1$	⇨	photon energies asymmetric



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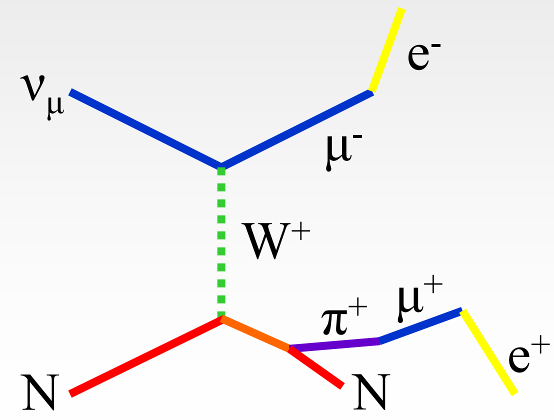
CCPiP Event Selection

- Neutrino events with 2 Michels:
  - First (Neutrino) subevent
    - Must be in beam spill
    - Tank Hits>175, Veto Hits<6
  - Need at least 2 Michels:
    - 20<Tank Hits<200, Veto hits<6
  - Monte Carlo event breakdown:
    - 78% resonant single pion – all resonant channels
    - 9% coherent pion production
    - 13% background (multi pion 7%, QE 4%, DIS 2%)
  - This data set is 2.62×10^{20} protons on target.
  - 36028 events : 4-5 times more than all bubble chamber data combined.



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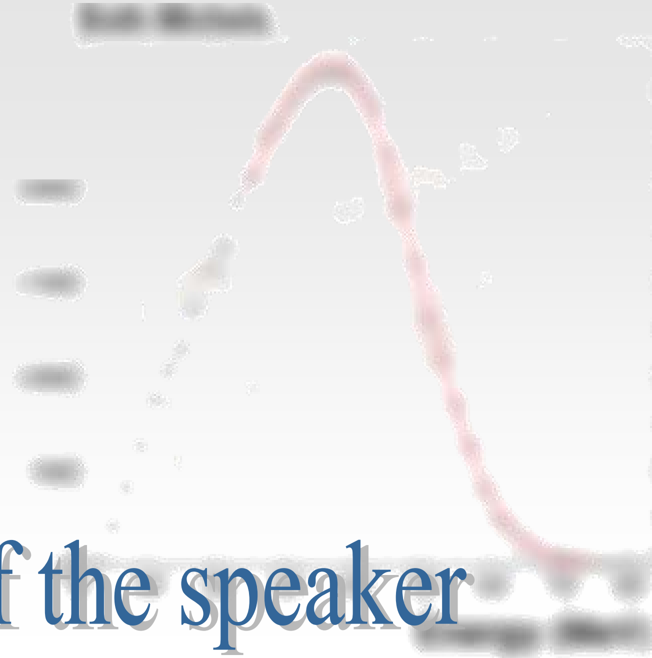
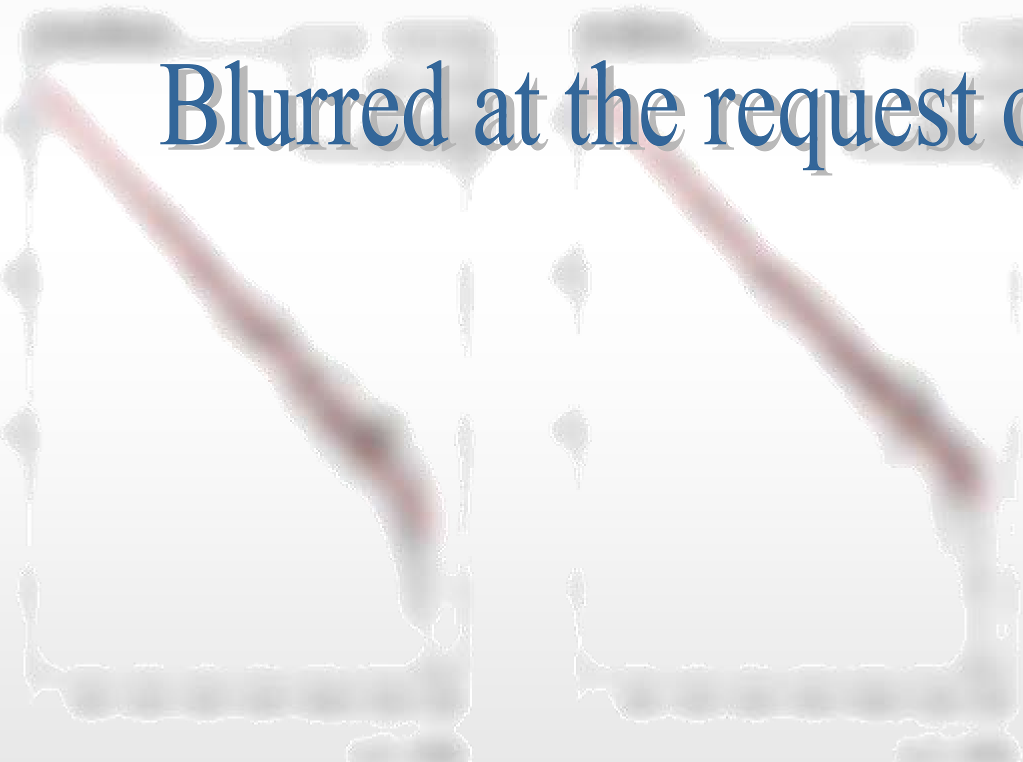
CCPiP Michels

Energy distribution fits Michel spectrum.

Separate into close and far samples – with respect to the muon track.





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Close (μ^-) capture on C (8%):

- τ=2026±1.5 ns
- Close Michels τ=2057±14 ns

Far (μ^+) do not capture:

- τ=2197.03±0.04 ns
- Far Michels τ=2215±15 ns

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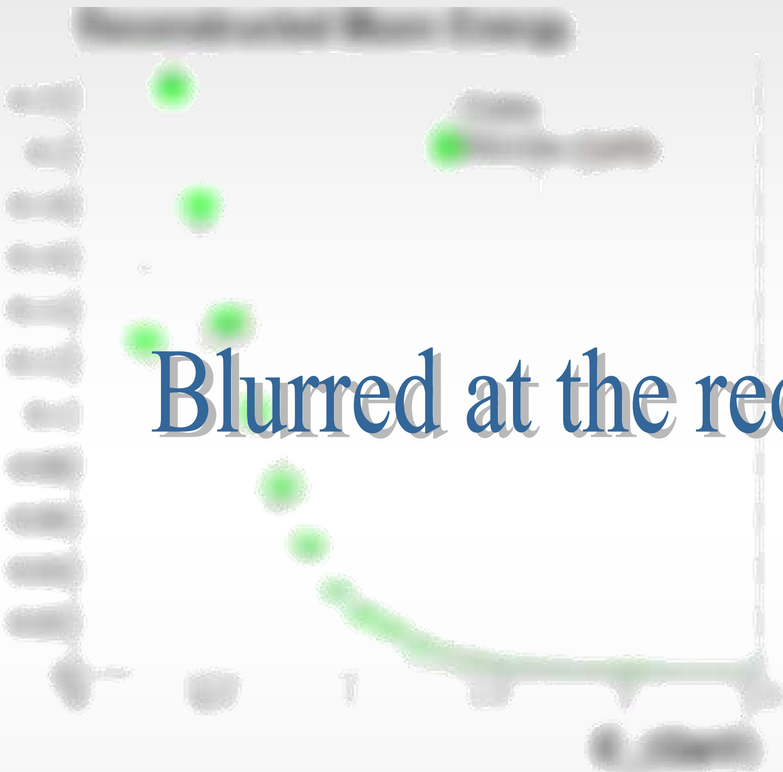
CCPiP Reconstructed Distributions

Muon energy from Čerenkov ring only.

All plots relatively normalized.



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Statistical errors only on data and MC.

Reasonable agreement in muon energy, perhaps some physics in angle.

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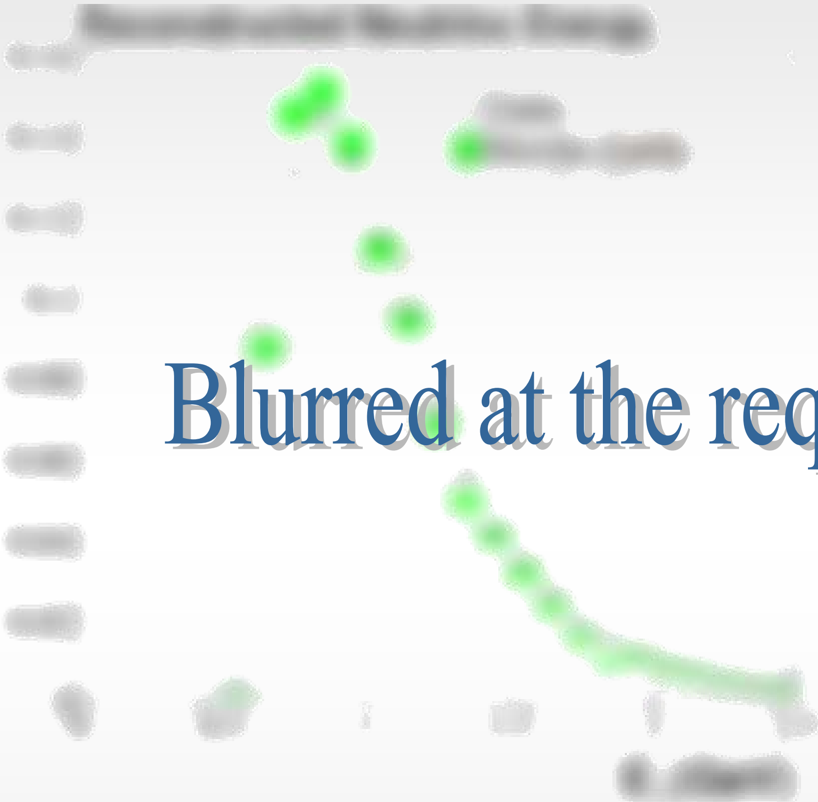
CCPiP : E_ν and Q^2



Low Q^2 suppression:

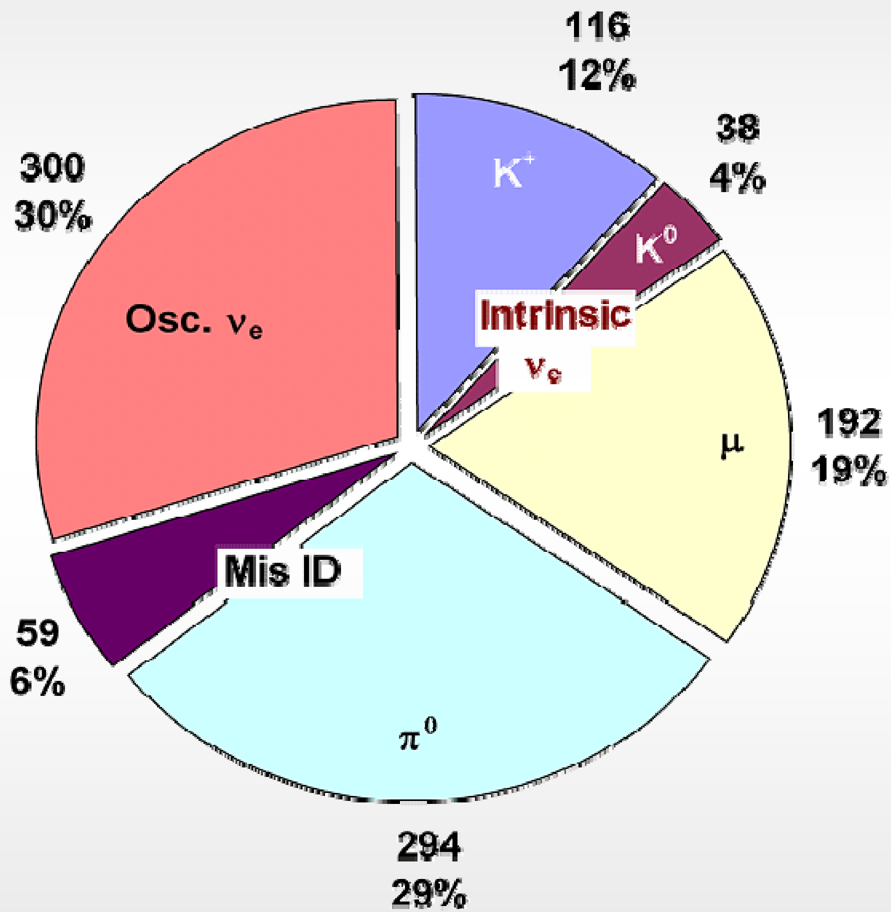
- Larger than in CCQE sample.
- K2K sees it too.

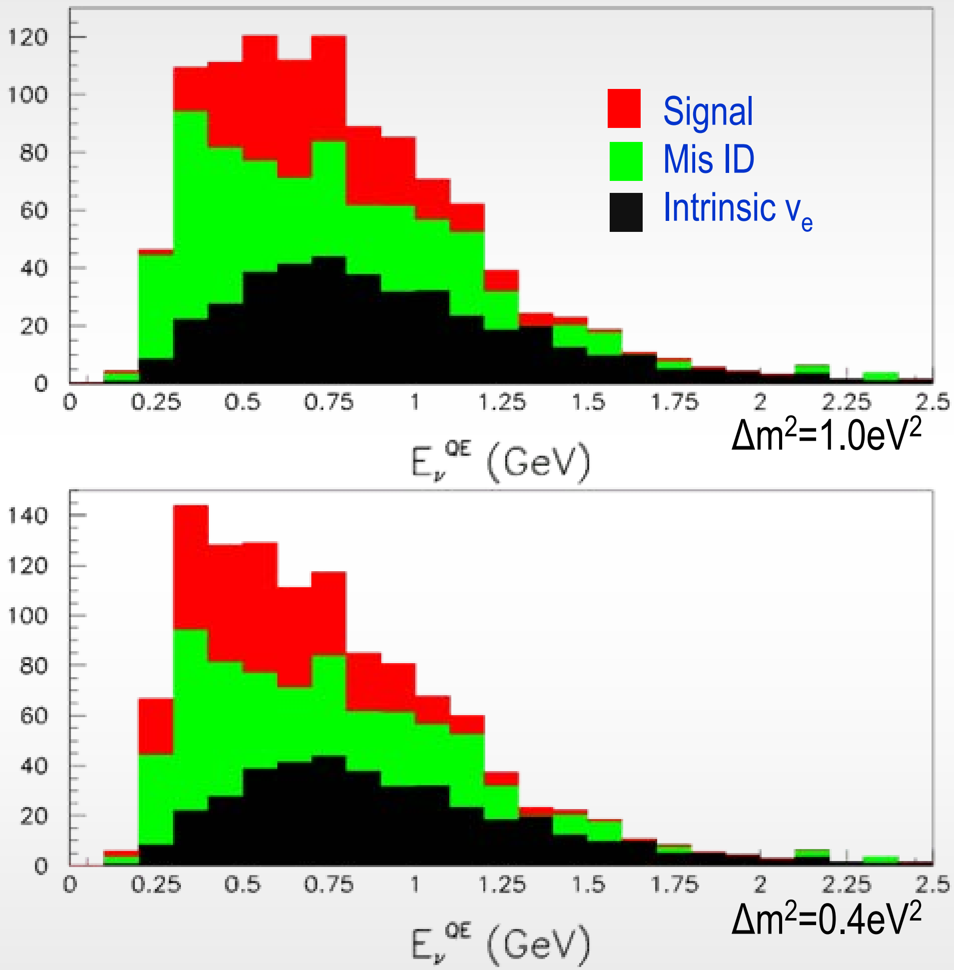
Blurred at the request of the speaker

Reconstruct CCPiP interaction as QE with a Δ(1232) resonant state instead of a recoil nucleon, and assume the target nucleon is at rest.

1×10^{21} pot

Estimates of $\nu_\mu \rightarrow \nu_e$ Appearance

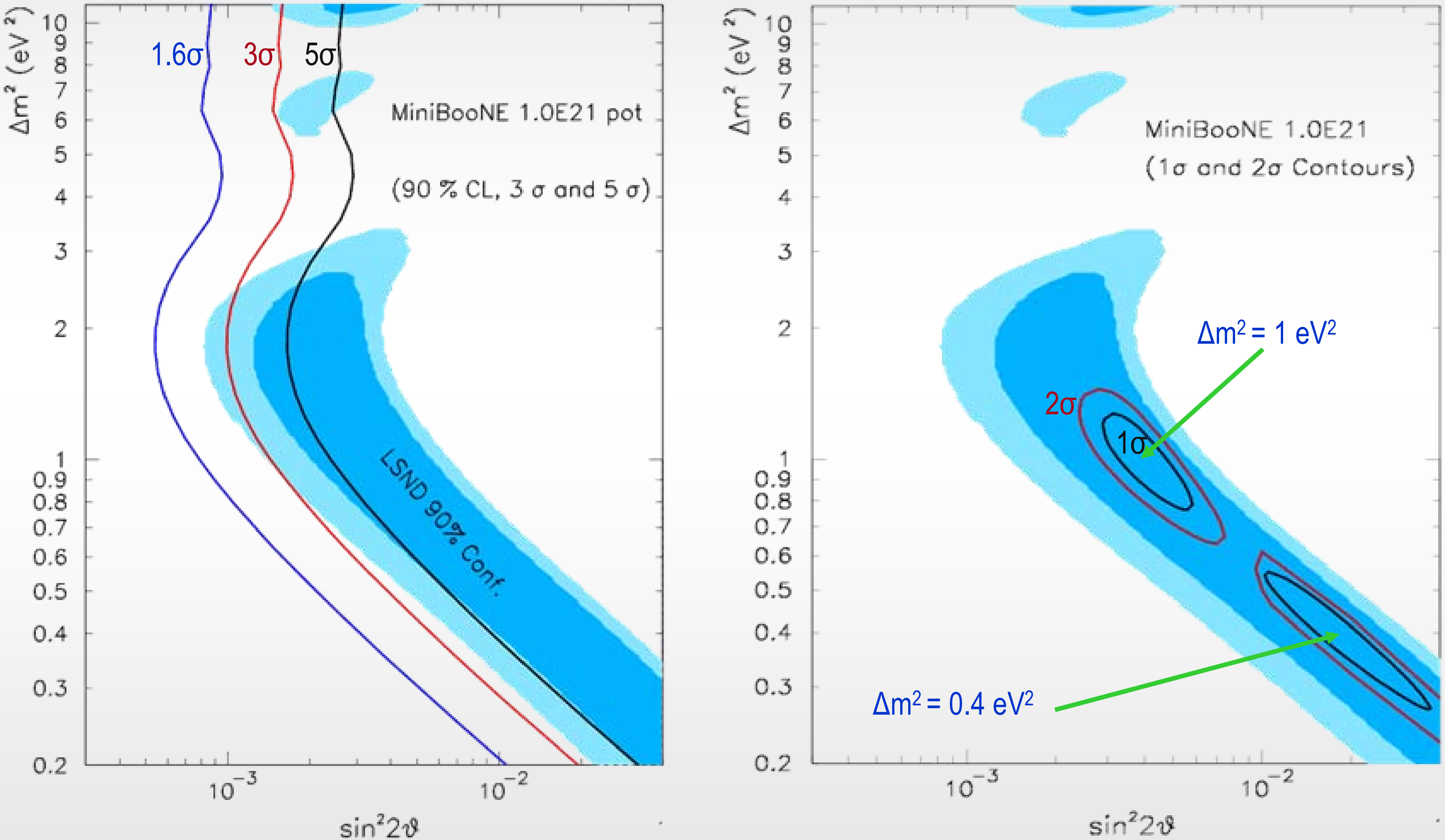




1× 10²¹ pot

MiniBooNE Oscillation Sensitivity

- systematic errors on backgrounds average ~5%



Looking ahead: FY 2006 and beyond

- MiniBooNE approved for FY06 running.
- Some or all of FY06 running may be in antineutrino mode: studies of O(1 GeV) $\overline{\nu}_\mu$ interactions.

shameless plug

- If MiniBooNE sees a signal, there is potential for a direct search for sterile oscillations at SNS or FNAL using a stopped pion source: hep-ph/0501013.

Conclusions

- MiniBooNE is running well.
- Currently 5.81×10^{20} protons on target.
- $\nu_\mu \rightarrow \nu_e$ appearance results by hopefully late 2005.